Delineation of Neighborhoods of Accra, Ghana Based on QuickBird Satellite Data

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Background

- Recent studies suggest that intra-city variations in poverty and health in developing countries (much of Africa) may be greater than differences between urban and rural populations.
- Our research team (SDSU, GWU, Harvard) analyzing census, health survey, and satellite image data sets to study spatial variations in poverty and health within Accra, Ghana.

Study Rationale

- Reporting units associated with census and health data are different in scale/size (i.e., MAUP/Ecological Fallacy).
- These disparate data sets must be aggregated and analyzed at a common scale (form analytical regions); a type of regionalization problem.
- Neighborhoods may be useful analytical regions.
- Also, useful to understand neighborhood-level effects on health practices and outcomes.
- Proportion or size of vegetation objects may be effective criterion for delineating Accra neighborhoods.

Accra, Ghana Study Area

Neighborhoods

- Geo-spatial objects within which human residents share common social-cultural behaviors and identities.
- Pertaining to health -- similar education and practices, and exposure to similar environmental factors.
- Figments of our imagination -- no real boundaries.
- Unique identity labels -- place specific.
Study Objectives

Address the question: How well can neighborhoods be delineated using object-based image analysis?

Test neighborhood delineation approaches based on high spatial resolution satellite (QuickBird) multispectral image data and object-based image analysis software (Definiens).

Strategy

• Use parsimonious approaches to delineating neighborhoods using satellite image data and object-based image analysis.
• Use census enumeration areas (EAs) as the minimum statistical unit.
• Aggregate EAs based on similarity in vegetation patch proportions or sizes derived from OBIA.
• Compare image-derived neighborhood maps with one derived from slum index (based on census data) and Duque spatial aggregation procedure.

Slum Neighborhoods
Low vegetation % & size; high impervious % & size

Moderate/High Socio-economic Neighborhoods
Low vegetation % & size; high impervious % & size

V = vegetation = Green
I = impervious = Blue
S = soil = Orange
Image Data

QuickBird Satellite Image

12 April 2002
18 km x 13 km scene extent; 6 km x 5 km subset
multispectral (GSD = 2.4 m)

Georeferenced at standard processing level
(CE90 = 23 m; RMSE = 14 m) to UTM projection

QuickBird Image -- Accra, Ghana
False color infrared composite

Study Area w/ Subset and Enumeration Areas
RGB = red, NIR, green

QuickBird Subset Image

Study Subset

QuickBird MS Segmentation
Unconstrained by EAs; Scale Factor = 800
QuickBird Pan Segmentation
Unconstrained by EAs; Scale Factor = 800

QuickBird MS Segmentation
Constrained by EAs; Scale Factor = 800

V-I-S Sub-Object Classification
Classification:
Nearest Neighbor Classifier
Input features: Border Index, Roundness, Brightness, Std. dev. of NIR, Length/Width, Density, Mean NDVI
Segmentation: Scale = 40, Shape = 0.4, Compactness = 0.8

Image-based Aggregation of EAs
Neighborhood generation based on:
* Mean Vegetated Proportion of EA Feature
* Mean Vegetation Patch Size per EA Feature
* “Spectral” Merge
* Segmentation

Processing Notes
Ocean objects were masked using the following rules:
* ‘Area’ > 2,000,000
* (min) ‘Y Distance to Image Border’ = 0

Basic OBIA-approach and rules for Neighborhood delineations:
* merge and segmentation parameters selected by trial and error process
* objective is to minimize the number of objects while avoiding elongated or low compactness objects
* assume that a neighborhood is constrained in size

Definiens Work-Arounds
* To use spectral merge and segmentation approaches on non-spectral features (e.g. vegetation fraction and patch size) the feature was exported as a shape (*.shp) file, converted to a raster layer, and imported to a new project as the only spectral layer.
* To import existing EAs (*.shp) input as thematic layer, and use extremely large scale parameter to limit object generation only by thematic data.
Vegetation Fraction: Simple Merge

Merge Threshold = 0.025 (i.e., 2.5%)

Black = original EAs
Red = Neighborhoods

Vegetation Patch Size: Simple Merge

Merge Threshold = 0.25

Black = original EAs
Red = Neighborhoods

Vegetation Fraction: Segmentation

Scale = 10, Shape = 0.2, Compactness = 1.0

Black = original EAs
Red = Neighborhoods

Vegetation Patch Size: Segmentation

Scale = 10, Shape = 0.2, Compactness = 1.0

Black = original EAs
Red = Neighborhoods

Neighborhoods Based on Slum Index & Duque Aggregation

Black = original EAs
Red = Neighborhoods

Characteristics of Neighborhood Maps

<table>
<thead>
<tr>
<th>Map Type</th>
<th>No.</th>
<th>Mean Size</th>
<th>S.D. Size</th>
<th>Mean Compact</th>
<th>S.D. Compact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enumeration Areas</td>
<td>644</td>
<td>30,229</td>
<td>110,431</td>
<td>1.26</td>
<td>0.33</td>
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<tr>
<td>Slum Index-Duque Aggregate</td>
<td>79</td>
<td>326,552</td>
<td>632,715</td>
<td>1.67</td>
<td>0.35</td>
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<tr>
<td>Veg % Segment</td>
<td>184</td>
<td>140,132</td>
<td>397,946</td>
<td>1.56</td>
<td>0.37</td>
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<tr>
<td>Veg % Merge</td>
<td>286</td>
<td>90,155</td>
<td>248,653</td>
<td>1.37</td>
<td>0.41</td>
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<tr>
<td>Veg Patch Size-Segment</td>
<td>309</td>
<td>83,444</td>
<td>293,914</td>
<td>1.49</td>
<td>0.32</td>
</tr>
<tr>
<td>Veg Patch Size-Merge</td>
<td>432</td>
<td>59,686</td>
<td>248,653</td>
<td>1.35</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Preliminary Conclusions

- Segmentation appears to be more promising than merge approach; accounts for size and compactness.
- Use of vegetation sub-objects (proportions with EAs) seems promising, though results inconclusive.
- Unconstrained (w/o EAs) image-only approach is challenging.
- Need reference data for training (based on field surveys)

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GEOBIA 2008 organizers